Improving The Bulk Formula For Sea-Surface Fluxes

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LONG-TERM GOAL

Derive a more flexibile form of the bulk forumula for sea-surface fluxes that does not require compliance with Monin-Obukhov similarity theory nor definition of the surface roughness length.

OBJECTIVES

The most important objectives are to generalize the bulk formula to: a) better approximate fluxes for stable weak-wind cases to accommodate the influence of unresolved mesoscale motions, b) account for reduced efficiency of moisture fluxes over cooler water, c) allow for confused seas and weak winds dominated by mesoscale motions through probability distributions of transfer coefficients and d) rexamine the bulk for formula for strong wind conditions. As a parallel investigation, the commonly used TOAGA COARE scheme will be modified.

APPROACH

The bulk formula will be generalized by analyzing several LoneEZ and recent CIRPAS Twin Otter aircraft data sets. Data from the CIRPAS Twin Otter April 08 Pilot Experiment will be emphasized in the initial analyses. This analysis will be supported by a new QC and analysis package contructed during the first year of the grant.

WORK COMPLETED

I participated in the April Twin Otter field program over Monterey Bay. I have analyzed a small subset of the new data, although corrected data sets have just become available. Much of this work concentrated on developing new software to analyze aircraft data in matlab, which will increase compatibility with the Twin Otter data provided by Djamal Khalif and Carl Friehe. My previous software in was in Fortran. Instead of converting software from Fortran to Matlab, I am reconstructing all the software from scratch. Secondary QC of the data is underway at the writing of this report.

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14. ABSTRACT

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RESULTS

New analysis software was tested on Twin Otter data from 23 April 2008, flown at 30 m above the sea surface in Monterey Bay. The data was orthogonally decomposed into a multiresolution basis set and truncated (low-pass filtered) at the 4 m length scale. The multiresolution cospectra provide well-defined scale dependencies for this data set and indicate that the turbulence extends to horizontal scales of about 500 m.

The flow is slightly unstable for most of the flight domain on this day. Consider the longest flight leg (Figure 1), which reveals a mix of transient modes and more stationary spatial variability. *While this example is informative, the nature of the mesoscale motions varies substantially from day to day and varies between different parts of the flight domain. As a result, probability distributions of transfer coefficients will be explored.*

The linear trend in the v-component (Figure 1) varies only slowly between aircraft passes. The 20 km oscillation in the wind field, most obvious in the crosswind flow (approximately the u-component), is an example of mesoscale modulation, which varies more significantly in time. The warm pool of 5 km width with 1 C amplitude (60 km position in Figure 1) and the broad surface temperature maximum at about 15 km distance are examples of more stationary forcing. The abrupt narrow warm pool at 60 km, and associated upward heat flux, enhances the turbulence sufficiently to be visible in Figure 1 (increase of w fluctuations, black line in Figure 1).

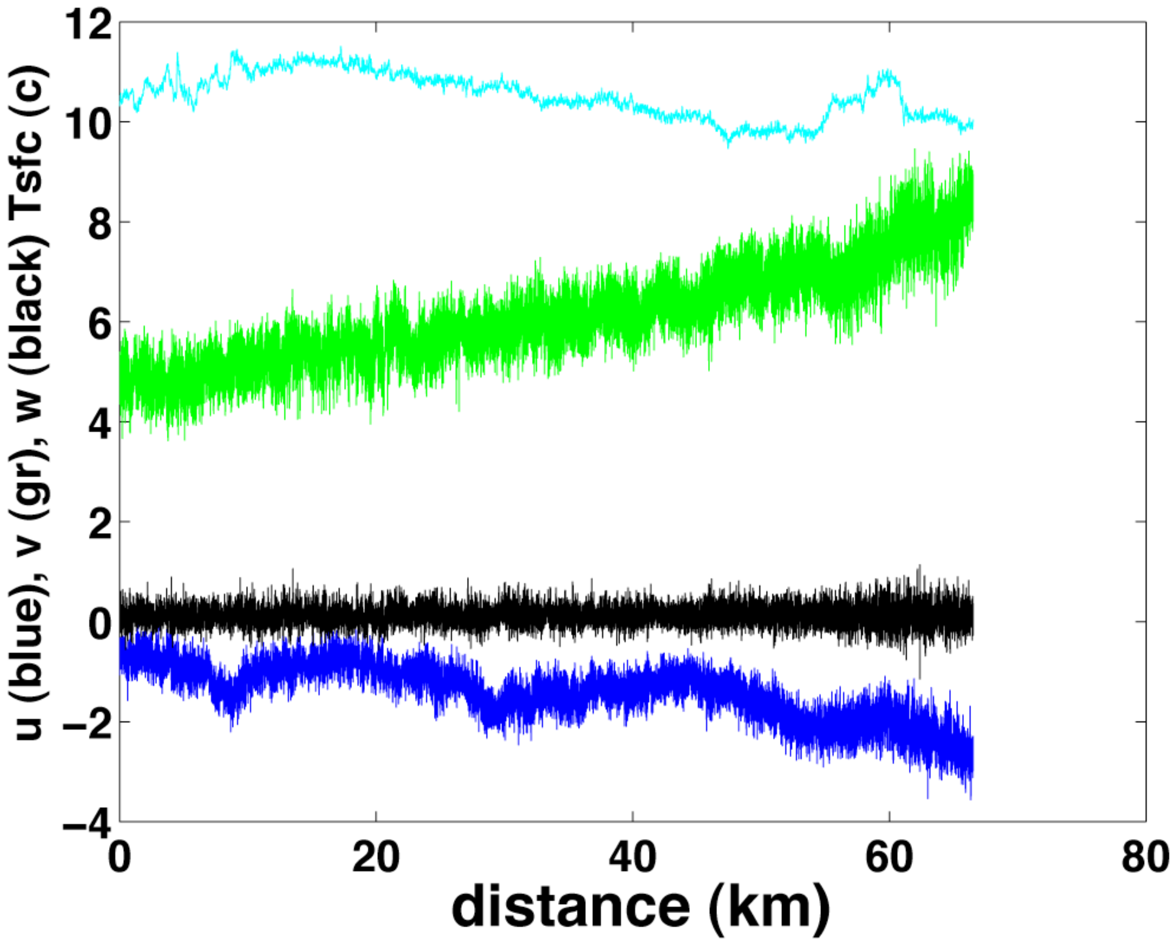

Figure 1. The u (blue), v (green) and w (black) wind components (ms^{-1}) and sea-surface temperature (cyan, C) as a function of along-track distance.

Closer inspection of the wind components in Figure 1 reveal semi-oscillatory behavior on horizontal scales of a few kilometers, whose importance is also supported by the velocity spectra. These oscillations are highly nonstationary and lead to little systematic flux, but appear to increase the variability of the turbulent flux. The fluxes vary more systematically only after spatial averaging over horizontal scales of a few kilometers or greater. For example, averaging variables over 4 km nonoverlapping windows leads to a systematic relationship between the drag coefficient and the surface bulk Richardson number (Figure 2).

More sophisticated analyses are required to partially isolate the relative roles of the different stationary and nonstationary modes on the flux. For example, the response of the flux to the 20 km oscillation will be examined in terms of phase averaging. However, isolation of the influence of the narrow warm pool will require compositing over repeated passes. Increased compositing allows shrinking the 4 km averaging window to smaller widths, yet retaining adequate sample size; that is, averaging repeated passes provides better spatial resolution with the same statistical reliability. This analysis will be pursued in November and December of this year. Considerable effort will be devoted to obtaining additional recent CIRPAS Twin Otter data sets to form a broader base for the analysis.

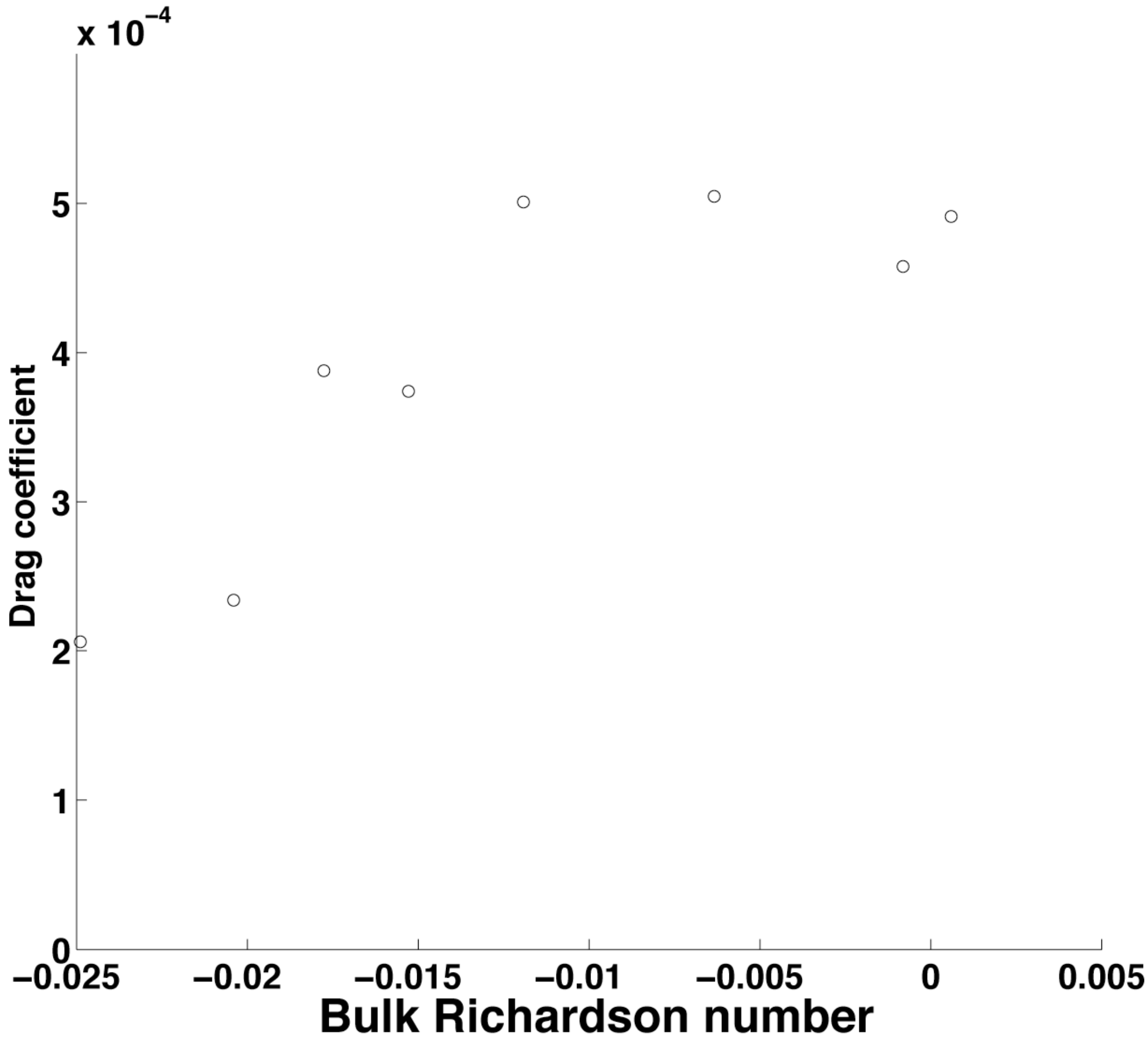

Figure 2. The drag coefficient as function of the bulk Richardson number for a flux averaging length of 4 km. The surface bulk Richardson number is based on the variables at the 30 m aircraft level and the sea-surface temperature.